Assessment of the performances of building energy retrofit using sensor networks for the monitoring of energy consumption and usages

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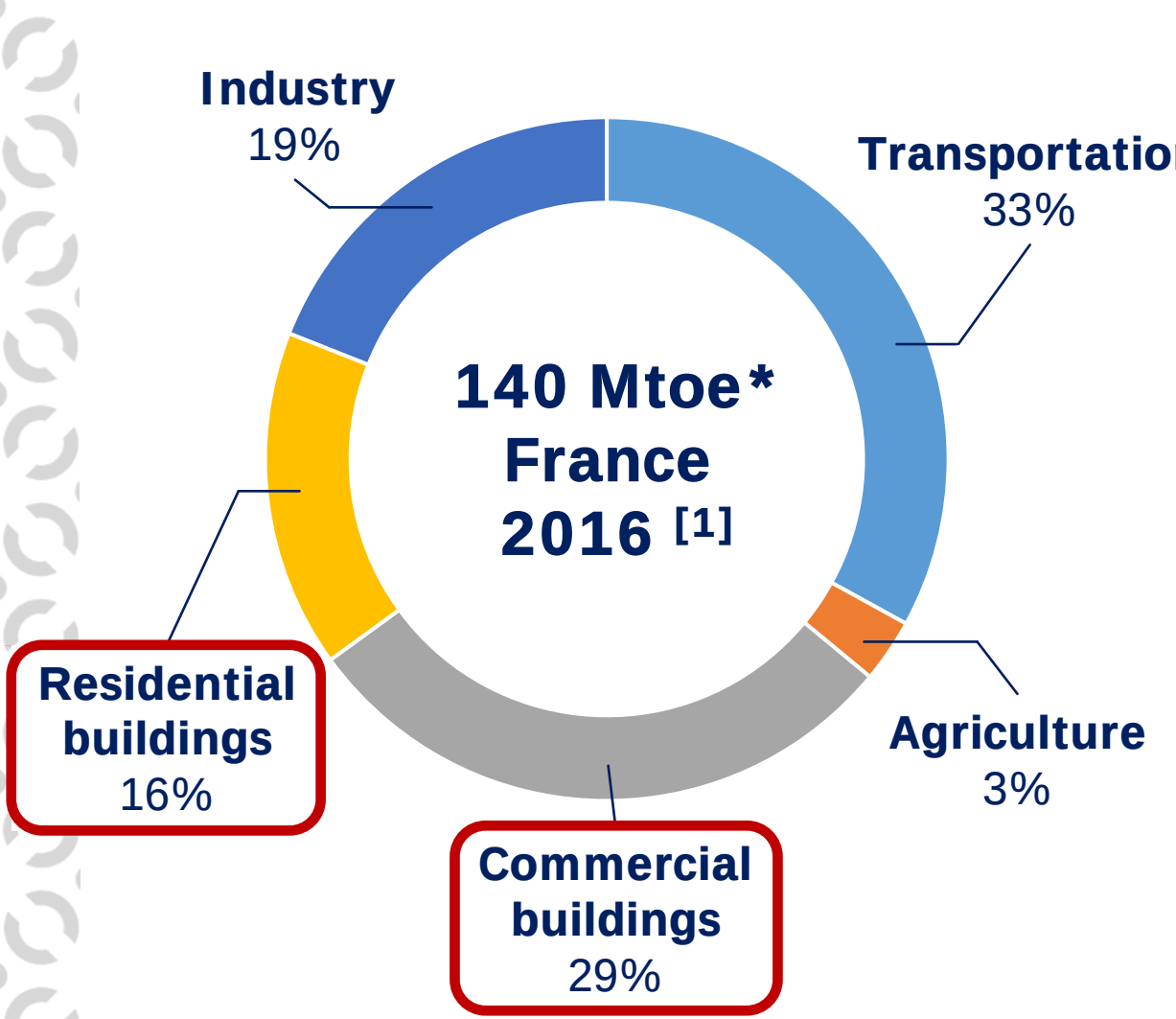
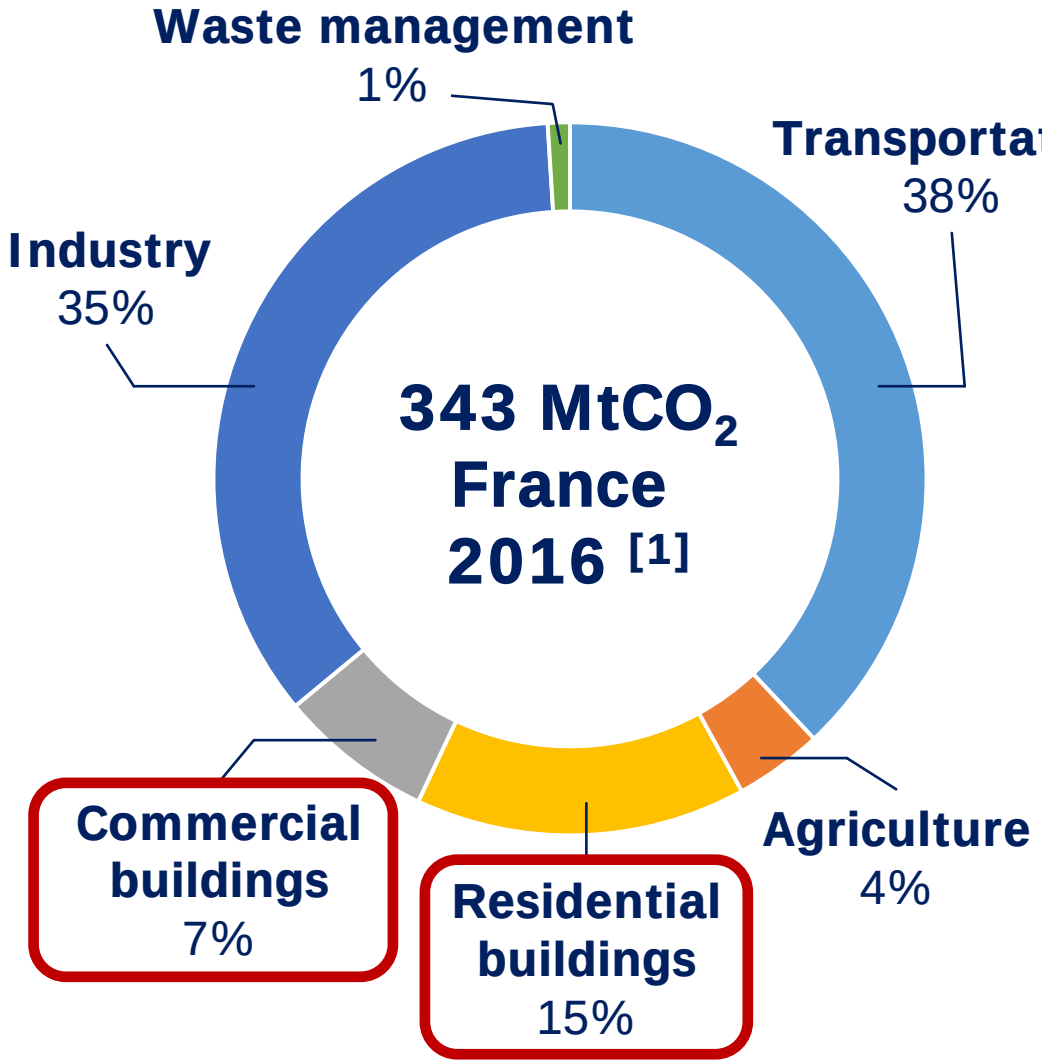
1. Introduction and context

Energy and environmental balance by end-use in France





[1] ADEME, 2018.
* Mtoe : million tons of oil equivalent

Tools for building energy efficiency : *Règlementation Thermique*

Règlementation Thermique (RT) – Thermal Regulation

⇒ Since 1974

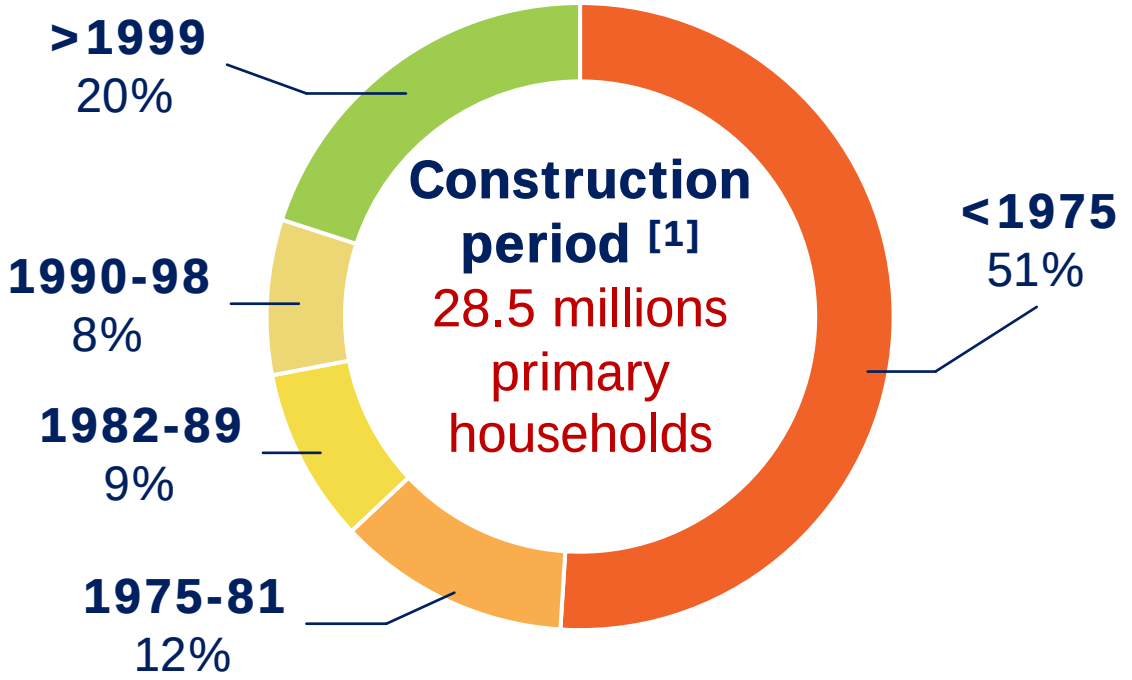
⇒ 2020 : includes environmental aspects

🎯 Targets

⇒ Residential and commercial buildings

⇒ New buildings

⇒ Existing buildings (retrofit) since 2007

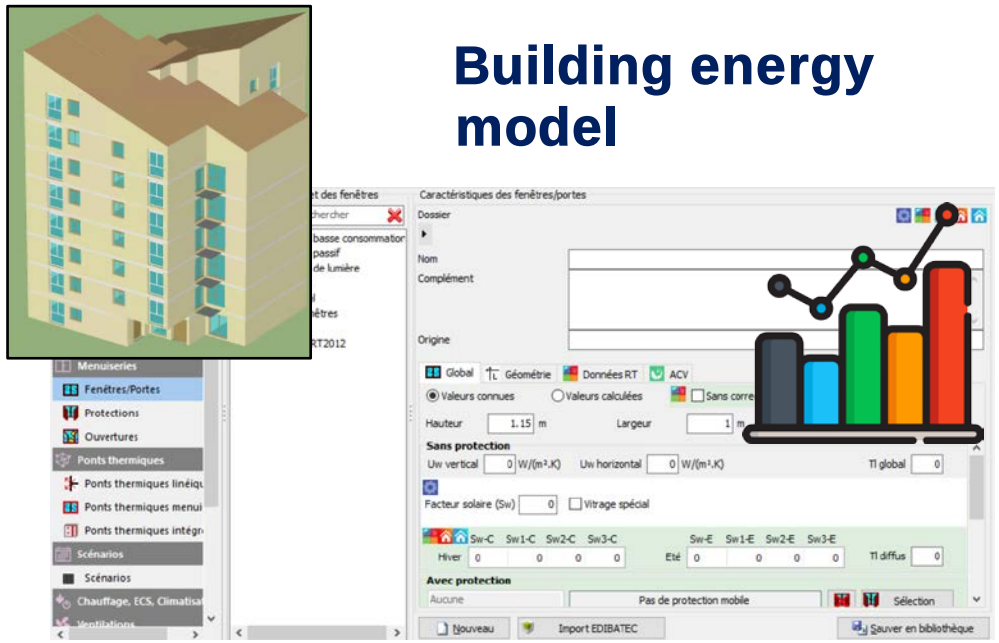


1% yearly renewal rate [2]

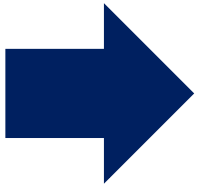
➡ Need for **efficient energy retrofit**

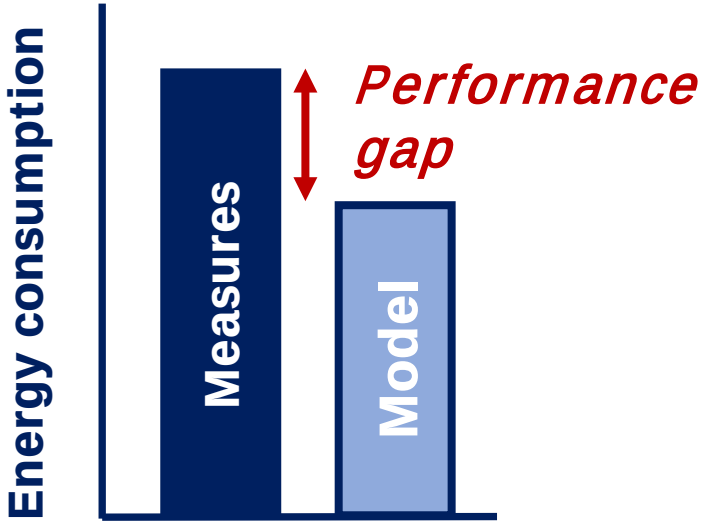
[1] ADEME, 2018.
[2] PACTE, 2017.

Energy performance gap



Building energy model





Definition : "A **significant difference between predicted** (computed) energy performance of buildings **and actual measured energy use** once **buildings are operational**." [3]

[3] P. de Wilde, 2014.

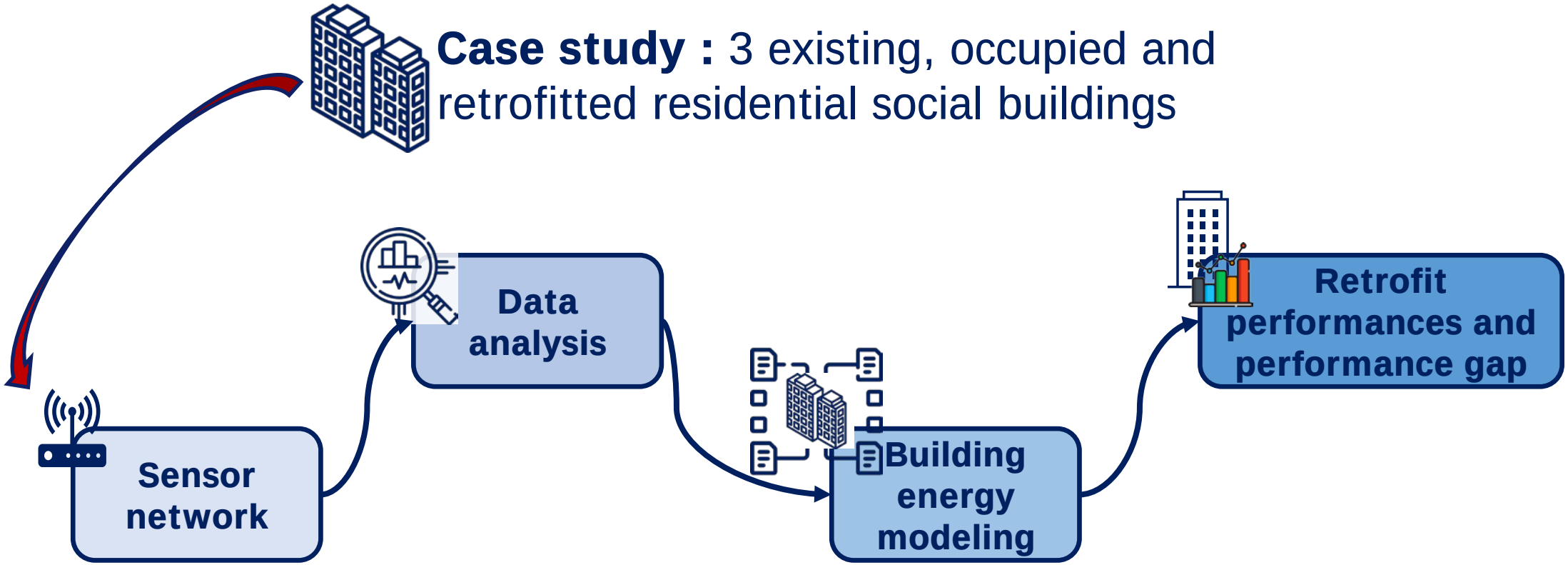
Research question

How do we study and decrease the performance gap to ensure the performance of retrofit campaigns ?

2. Research project summary

Assessment and study of energy performance gap in a deep energy retrofit context

Case study : 3 existing, occupied and retrofitted residential social buildings



Description of the case study

⇒ 3 residential buildings
⇒ 63 social housings
⇒ Built in 1974
⇒ Living area: 3,825 m²
⇒ Central heating and DHW*

Deep energy retrofit over 2020-2021

Building envelope, windows and doors, ventilation system, heaters, new central geothermal hot water system

*DHW : Domestic Hot Water

3. Sensor network

To characterize energy consumption, IEQ and occupants' behavior

Descriptive summary of the sensor network

Measurements

⇒ Buildings & systems
⇒ 8 housings
⇒ Local weather

179 sensors
Over 3 years of supervision

Targets

⇒ Energy consumption
Heating, DHW, electricity, natural gas
⇒ Indoor environment quality (IEQ)
⇒ Occupants' behaviors
⇒ Local weather

Data collection

⇒ Wireless
Radio (LoRa) & cellular (GPRS) networks
⇒ Acquisition: 1-minute to 1-hour time-step

Thermal energy meter
Heating/DHW energy consumption at building scale

Examples of sensors

Electricity et natural gas

Pulse sensor for Linky smart meter

Sensor with clamp ampere meters for electric switchboard

Pulse sensor for Gazpar smart meter

Examples of sensors

Heaters and DHW

Surface temperature of heaters

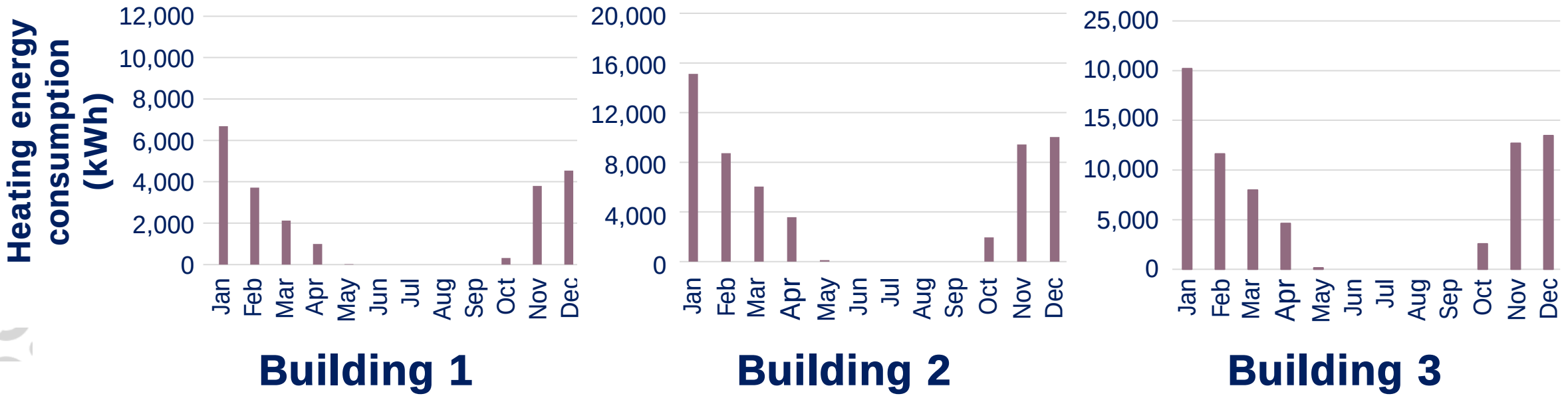
Surface temperature of DHW pipes

4. Analysis of the energy performance gap in a deep energy retrofit context

Heating period
2021-2022

Heating energy consumption

Measures vs. models

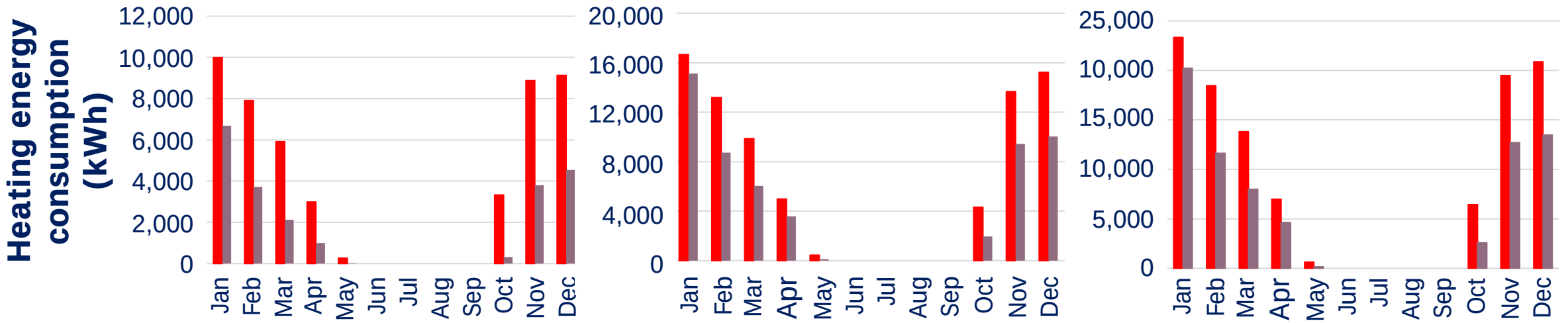


Building energy models	22,182 kWh	55,019 kWh	73,307 kWh

Heating period
2021-2022

Heating energy consumption

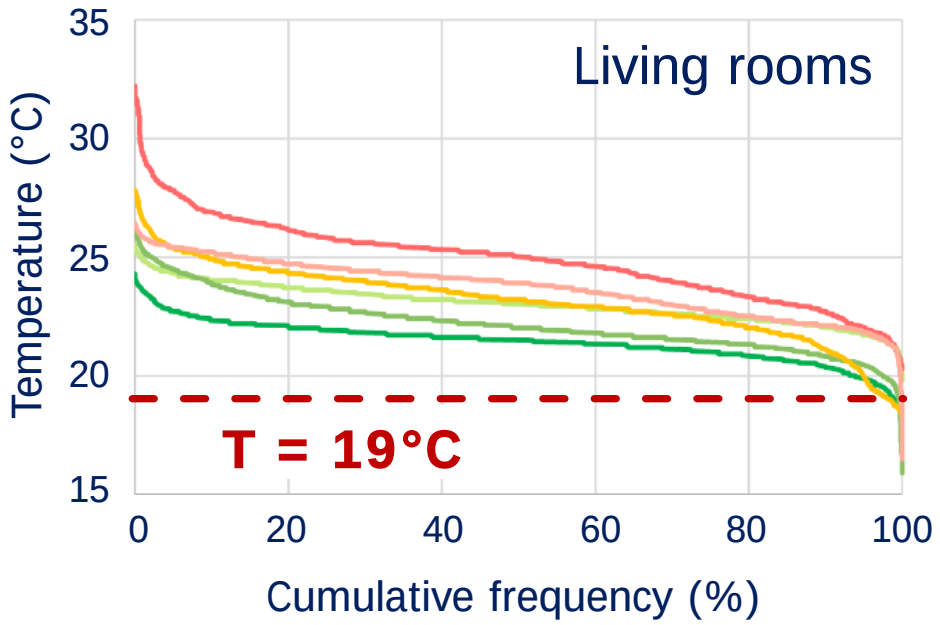
Measures vs. models



	Building 1		Building 2		Building 3	
Measures	48,400 kWh		78,346 kWh		110,005 kWh	
Building energy models	22,182 kWh	-54%	55,019 kWh	-30%	73,307 kWh	-33%

Large gap between energy models and measures

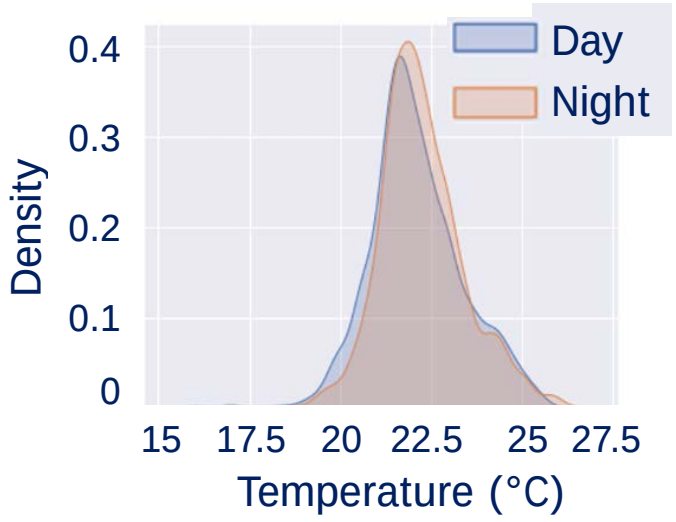
Data analysis: indoor temperature

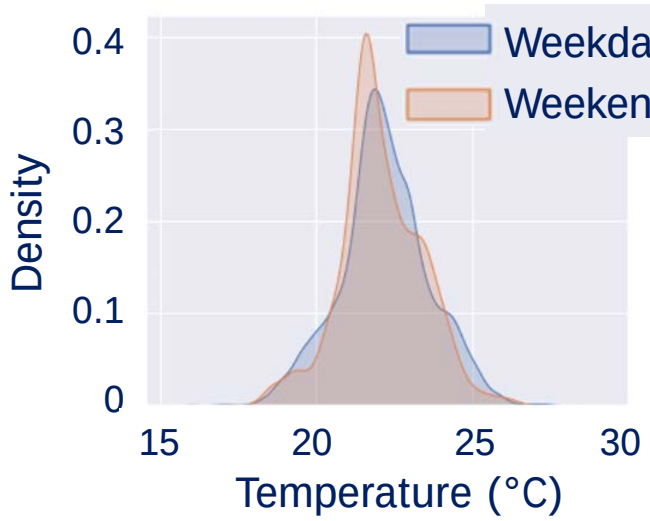


	Average (°C)
B1/2	21.4
B1/3	23.0
B2/0	22.2
B2/5	23.1
B3/0	24.9
B3/2	23.7

→ **Indoor temperature >19°C**

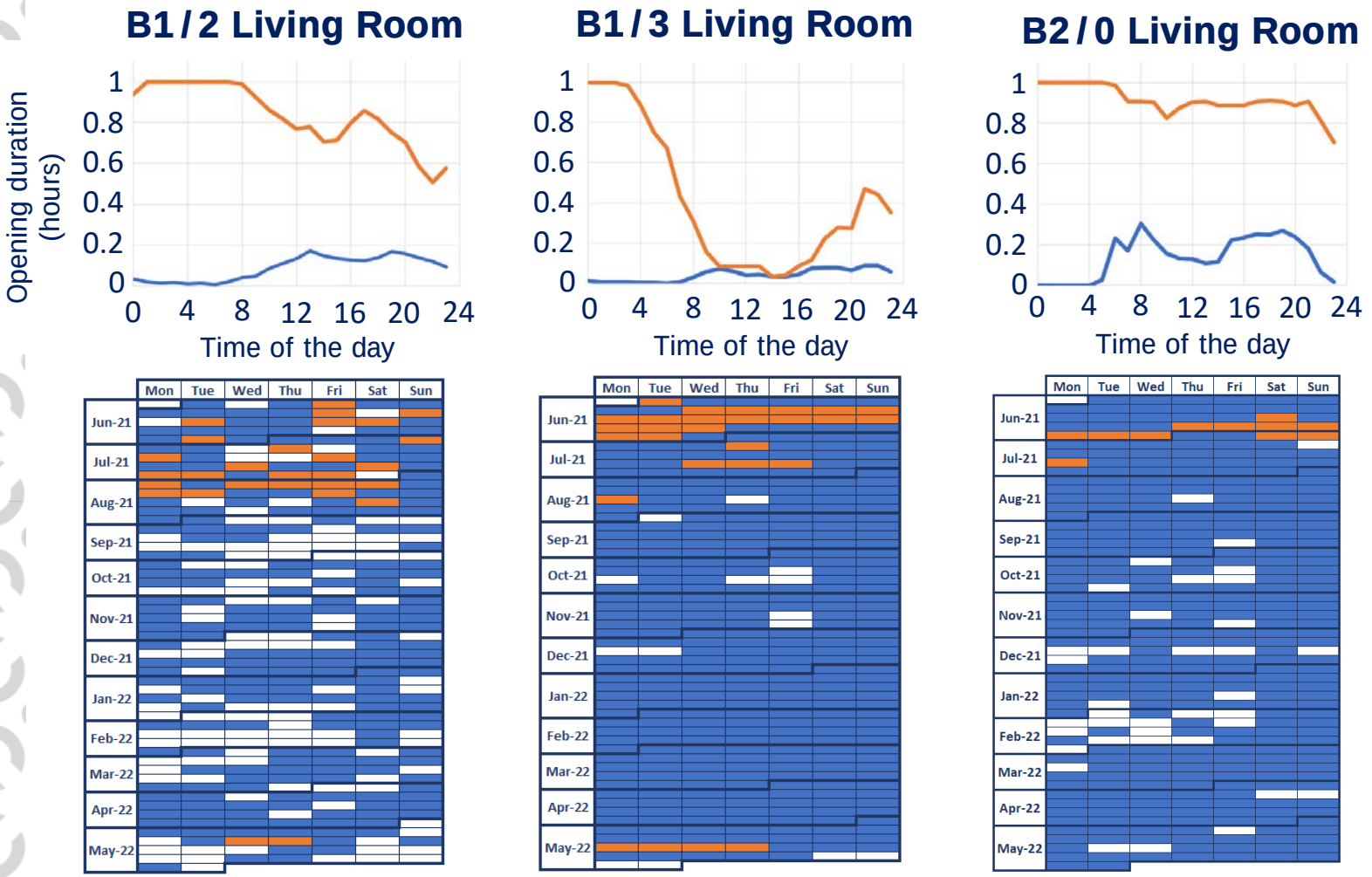
Apartment B2/0 (GF)





→ **No heating regulation**

Data analysis: window opening



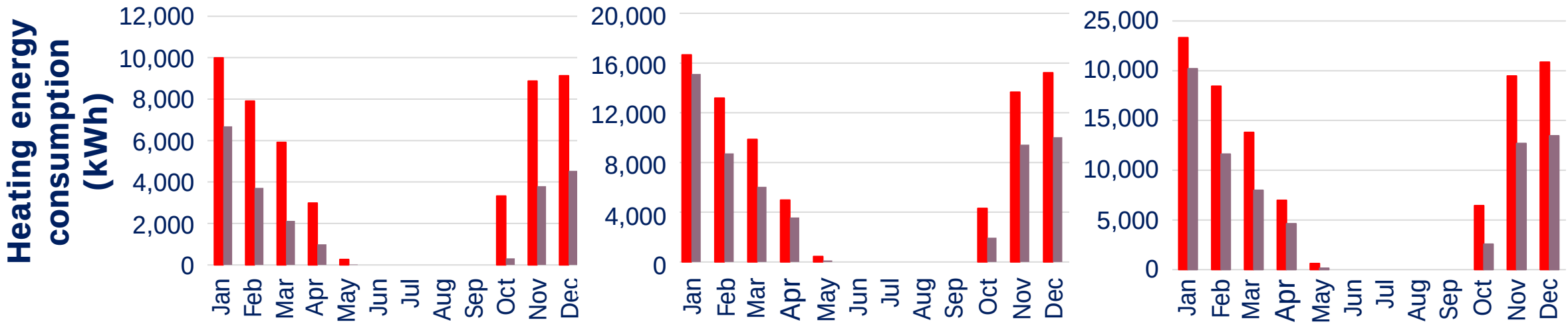
Large variety of occupants' behaviors

Significant impact on heating and building energy consumption

Heating period
2021-2022

Heating energy consumption

Measures vs. models



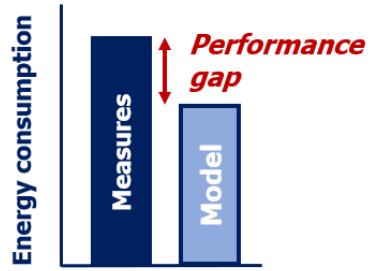
	Building 1		Building 2		Building 3	
Measures	48,400 kWh		78,346 kWh		110,005 kWh	
Building energy models	22,182 kWh	-54%	55,019 kWh	-30%	73,307 kWh	-33%
Pre-retrofit regulatory study	67,135 kWh	+39%	96,244 kWh	+23%	110,585 kWh	+0,5%

5. Conclusions

Conclusions

Efficient energy retrofit

Decrease the performance gap



Instrumentation protocols

⇒ Characterization of usages
⇒ Monitoring of IEQ and energy consumption
⇒ Assessing and **ensuring** performances of retrofit campaigns

Incentive towards the massification of global retrofit actions

THANK YOU FOR YOUR ATTENTION

Assessing building energy consumption and performances

« Bottom-up » building energy modeling

Micro / system scale

Building scale

Enveloppe

+

Usages & occupancy

+

Energy systems

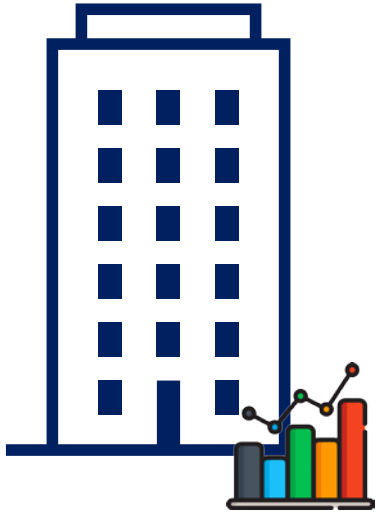
+

Operation scenario

+

Weather & surroundings

Combining



Building energy model (BEM)

Tools for efficient building energy retrofit

Regulatory tools

⇒ *Règlementation Thermique*

⇒ *Plan de Rénovation Energétique de l'Habitat* (2013) [4]

⇒ *Décret Tertiaire* (2019) [5]

Technological tools

⇒ European directive on smart meters (*France : Linky, Gazpar*) [6]

⇒ Internet of Things IoT, Building Energy Management Systems BEMS (GTB/GTC)

Strategies to target performance gap decrease [7]

Field data collection and analysis

Characterization of energy-related behaviors

[4] ADEME (PREH), 2018.
[5] Ministère de la Transition Ecologique, 2019.
[6] P. Zou et al., 2018.
[7] F. Tounquet, C. Alaton, 2020.